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Age, Reproduction, Growth, Condition and Diet of the Introduced Yellow Bass, Morone Mississippiensis, in Barren River Lake, Kentucky

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AGE, REPRODUCTION, GROWTH, CONDITION AND DIET OF THE INTRODUCED YELLOW BASS, MORONE MISSISSIPPIENSIS, IN BARREN RIVER LAKE, KENTUCKY

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Introduction of fish species to North American drainages has occurred for over 100 years. Introduced fish species have been documented to have adverse effects on both the environment and native species of the drainage into which they have been introduced. To better understand the effects that introduced species may have on a particular drainage, it is essential to understand aspects of the introduced species' life history. The objectives of the current study is to quantify the age, reproduction, growth, condition and diet of the yellow bass, *Morone mississippiensis*, in Barren River Lake, Kentucky. Monthly collections from three areas on Barren River Lake were made via a boat-mounted electrofisher from March 2008 to March 2009. Fish age was estimated by examining the sagittal otoliths of each individual. Reproductive condition was assessed using the mean gonadosomatic index (GSI) of all sexually mature individuals by month. Yearly growth rates were estimated by computing the mean length at age for each age class and subsequent calculation of the von Bertalanffy growth function (VBGF). To estimate the condition of yellow bass as it changed throughout the sample period, relative weight of each individual was calculated and the mean monthly relative weight was calculated. To examine the diet of yellow bass, diet items were identified to the lowest practical taxonomic level. Then, dry weight of each diet item was estimated and pooled by season to assess the season changes in the diet of yellow bass. Individuals of age group 3 were the most frequent. Mean GSI was significantly higher in March, April and May of 2008. Calculation of the VBGF yielded 254.7 mm as the maximum attainable mean total length of yellow bass in Barren River Lake. VBGF predicted mean total lengths of age classes 0-8 were as follows: 21.7 mm, 64.4 mm, 99.2 mm, 127.7 mm, 151.0 mm, 170.0 mm, 185.5 mm, 198.2 mm, and 208.5 mm. Relative weight was highest in summer. The diet of adult and sub-adult yellow bass relied heavily on chironomid larvae and pupae throughout the year, although diet item consumption was very low in winter. Young-of-year gizzard shad (*Dorosoma cepedianum*), however, became the most important adult diet item in the spring and summer. To better understand the impacts that the introduced yellow bass has on the ecosystem of Barren Rive Lake, a multi-year study including an estimation of relative abundance is recommended.

Introduction

Introduction of fish species to North American drainages is well-documented (Gido and Brown 1999) and has occurred for over 100 years (Mills et al. 1993; Whittier and Kincaid 1999; Rahel 2000). An introduced species can be defined as a species that has been transported by humans to an area where it did not naturally occur. In contrast, native species naturally occur in the area they are found (Miller et al. 2001; Chapman et al. 2003). An exotic species may be defined as a species that did not naturally occur in North America before introduction (Kurdila 1995). Routes of introduction, intentional and unintentional, include bait-bucket introduction, fish stocking, accidental escape of aquaculture species, and alteration of drainages by humans (Whittier and Kincaid 1999; Rahel 2000; Hoodle 2004). Fish species introductions have been reportedly deleterious to abiotic and biotic aspects of aquatic systems (Herbold and Moyle 1986; Vitousek et al. 1997; Angeler et al. 2002). For example, feeding habits of introduced carp (*Cyprinus carpio*) have been associated with increased turbidity, increased phosphorus and increased ammonia concentrations in the water column (Zambrano and Hinojosa 1999; Miller and Crowl 2006; Coulter et al. 2008).

Introduced fish species have an impact on native fishes through predation, competitive displacement, hybridization, and habitat alterations (Meffe 1985; Townsend and Crowl 1991). In many cases, introduced species can replace or cause the local extirpation of native species (eg., Meffe 1984; Flecker and Townsend 1994; Shepard et al. 1997; Hobbs and Mooney 1998; McDowell 2003; Hoodle 2004). Previous studies show that native fish species can be affected by introduced species through predation (e.g., Eschmeyer 1957; Meffe 1984, 1985; Gamradt and Kats 1996). The mosquitofish

(*Gambusia affinis*), a poeciliid native to the eastern and central Neararctic region (Meffe 1984; Hoodle 2004), has been deliberately introduced to many drainages west of the Mississippi River for purposes of mosquito population control (Krumholz 1948). *Gambusia affinis* introductions have been linked to the severe extirpation and near extinction of the native Sonoran topminnow (*Poeciliopsis occidentalis*) through predation (Meffe 1984, 1985).

Predation by introduced fishes have also affected economically important native species. The sea lamprey (*Petromyzon marinus*) has a North American native range that includes Lake Ontario and the New York Finger Lakes (Hubbs and Pope 1937; Lawrie 1970). The Niagara Escarpment served as a historical barrier to sea lampreys migration upstream to the Great Lakes Basin west of Lake Ontario (Hubbs and Pope 1937). The subsequent construction of the Welland Canal connected Lake Ontario to Lake Erie and subsequently the whole of the Great Lakes Basin, providing an invasion route for the sea lamprey. Sea lampreys were established in Lake Erie by 1922 (Hubbs and Pope 1937; Shetter 1949), reported in Lake Michigan and Lake Huron by 1937 (Hubbs and Pope 1937; Shetter 1949; Lawrie 1970), and reached Lake Superior by 1946 (Lawrie 1970).

Sea lamprey are obligate ectoparasites with a round mouth lined with rows of teeth capable of creating suction for attachment to the host. Using a tongue covered in sharp plates, lampreys scrape through the host fish's scales to draw blood. The blood flow from the host is facilitated by the lampreys' capability to inject an anticoagulant agent into the host fish (Hubbs and Pope 1937; Shetter 1949). By the late 1940s, it was clear that the introduction of sea lampreys to the upper Great Lakes region was having a drastically negative effect on the population of lake trout (*Salvelinus namaycush*), an important Great Lakes sport fish that supported a healthy commercial fishery (Eschmeyer 1957). There was a marked decline of commercial fishing yields from 1944 to 1949 in the Upper Great Lakes: 2.7 million kilograms to 0.18 million kilograms in Lake Huron, 3.1 million kilograms to 0.16 million kilograms in Lake Michigan, and 2.1 million kilograms to 0.23 million kilograms in Lake Superior (Eschmeyer 1957; Lawrie 1970; Hansen 1999).

Other fish species that have caused harm to native fish species through predation include rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), and smallmouth bass (*Micropterus dolomieui*). Rainbow trout have had a negative impact through predation on a Little Colorado River endangered native species, the humpback chub (*Gila cypha*; Marsh and Douglas 1997). Predation by introduced rainbow and brown trout have had a negative effect on populations of native galaxiids in New Zealand (McDowell 2003; Townsend and Crowl 1991). Introduced smallmouth bass have a negative effect on populations of native prey species in fourteen Ontario Lakes (MacRae and Jackson 2001).

Introduced fish species may also alter native populations through competitive displacement (Townsend and Crowl 1991; McDowall 2003). In the presence of large introduced predators, native fish, such as bluegill (*Lepomis macrochirus*) and pumpkinseeds (*L. gibbosus*), shift usage of optimal to less optimal foraging areas (Mittelbach 1988; Townsend and Crowl 1991). Introduced brown trout, rainbow trout, and brook trout (*Salvelinus fontinalis*) have used most annual production of benthic invertebrates in several New Zealand rivers, lakes, and streams (Flecker and Townsend 1994; McDowall 2003). This has severely limited the availability of important prey items for declining populations of native galaxiid fishes (Townsend and Crowl 1991; McDowall 2003).

Non-native species introductions can pose a serious risk to native populations due to introgressive hybridization (Rymer and Simberloff 1996; Shepard et al. 1997; Fausch et al 2001; Rubidge and Taylor 2005), the interbreeding of genetically distinct species resulting in the destruction of the genetic integrity of the subsequent reproductively viable progeny (Allendorf and Leary 1988; Rymer and Simberloff 1996). Substantial population declines, local extirpations, and the decay of genetic integrity of westslope cutthroat trout (*O. clarki lewisi*) have been attributed to the invasion of introduced rainbow trout, which readily hybridize with westslope cutthroat trout (Allendorf and Leary 1988; Rymer and Simberloff 1996; Shepard et al. 1997; Rubidge and Taylor 2005). Destruction of the genetic integrity due to introgression with introduced rainbow trout has been associated with an approximate 95% reduction in westslope cutthroat trout's historical native range, from about 93,000 km of historical stream occupancy to about 4,300 km (Shepard et al. 1997). Hybridization with introduced rainbow is also considered a threat to the genetic integrity of the Apache trout (*O. apache*) and Gila trout (*O. gila*; Dowling and Childs 1992).

Introductions of domestic brown trout (*S. trutta*) have introgressed with three native northern Italian subspecies of brown trout (*S. t. fario, S. t. maramoratus*, and *S. t.* carpio; Giuffra et al. 1994). In Sweden, the arctic char (*Savelinus alpinus*) have been extensively introgressed with introduced lake trout (*S. namaycush*; Rymer and Simberloff 1996). The sheepshead minnow (*Cyprinodon variegates*), accidentally introduced by anglers through bait-bucket introduction, has introgressed with the native Pecos pupfish

(*C. pecosensis*) throughout more than half of its native range in the Pecos River (Echelle and Connor 1989). Genetic integrity of the Guadalupe bass (*Micropterus treculi*) populations in the Guadalupe River drainage have been threatened by introgressive hybridization with introduced smallmouth bass (*M. dolomieui*; Whitmore 1989; Stark and Echelle 1998).

Species introductions may impact populations of native fish through habitat alteration (Meffe 1985; Zambrano and Hinojosa 1999). The quintessential example of these effects is the habitat alteration caused by introduced common carp *Cyprinus carpio*, in North America (e.g., Forester and Lawrence 1978; Crivelli 1983; Zambrano and Hinojosa 1999; Miler and Crowl 2006; Coulter et al. 2008). Carp were introduced from eastern Europe into North American lakes in the mid-1800s as a source of food for humans, and has since become well established in North America (Crivelli 1983; Mills et al. 1993; Parkos et al. 2003; Miller and Crowl 2006; Coulter 2008). Carp are benthivorous, preying heavily on submerged macrophytes and sifting through the benthos for macroinvertebrates (Zambrano and Hinojosa 1999; Miller and Crowl 2006). Feeding habits of introduced carp are associated with increased turbidity, increased phosphorus and ammonia concentrations in the water column, and decreased density of submerged vegetation (Zambrano and Hinojosa 1999; Miller and Crowl 2006; Coulter et al. 2008). Habitat alterations by introduced carp have indirect effects on the zooplankton community by increasing the concentration of dissolved solids in the water column (Parkos et al. 2003) and by disturbing the dormant benthic stage vital to zooplankton recruitment (Angeler et al. 2002). Subsequent depletion of zooplankton populations, along with the depletion of submerged macrophytes, can reduce the production of forage fish, affecting the food web of the entire aquatic ecosystem (Zambrano et al. 2001).

Kentucky supports a high diversity of fish species in the United States, behind only Alabama and Tennessee (Burr and Warren 1986). A total of 242 species are known to or have occurred in Kentucky, 16 of which are reported as introduced. The 16 introduced fish species in Kentucky are the alewife (*Alosa pseudoharengus*),goldfish (*Carassius auratus*), grass carp (*Ctenopharyngodon idella*), common carp, silver carp (*Hypophthalmichthyes molitrix*), white catfish (*Ameiurus catus*), northern pike (*Esox lucius*), coho salmon (*Oncorhynchus kisutch*), rainbow trout, brown trout, brook trout, lake trout, brook stickleback (*Culaea inconstans*), the striped bass (*Morone saxatilis*), redbreast sunfish (*Lepomis auritus*), and redeye bass (*Micropterus coosae*; Burr and Warren 1986).

Collecting information pertaining to introduced species' life history traits may provide a better understanding of the impacts that they may have on aquatic systems. Studying the life history traits of an organism involves defining biological characteristics important to the understanding of the success of the study species, creating mathematical representations of these characteristics using collected data, and making predictions based on these mathematical representations (Stearns 1976). Biological characteristics important to the understanding of the success of the study species include but are not limited to: reproductive habits, feeding habits, length and weight frequencies, growth rates, and age structure of the population (Cole 1954; Schaffer and Elson 1975; L'Abee-Lund et al. 1989; Murphy and Willis 1996).

Man-made reservoirs are unique artificial habitats created by the construction of a dam across a stream or river channel. The resultant obstruction of flow allows the capture of runoff waters and subsequent flooding of a predetermined area of the floodplain creating an artificial lake. This creates lentic habitats in an area where these habitats did not necessarily occur naturally.

After a reservoir fills, fish species present in the original river populate the new lake. Because these fish species have evolved in the river habitat, they usually use the littoral zone in the lake while leaving the newly created pelagic zone relatively unpopulated. The pelagic zone is often characterized by high production but very few fish species at the top of the food web, creating open niches that introduced lentic species can fill.

The yellow bass, *Morone mississippiensis* (Perciformes: Moronidae), is native to large rivers and oxbow lakes in the Mississippi River drainage (Helm 1964; Driscoll and Miranda 1999), but is non-native to Barren River drainage. Because yellow bass prefer the slower moving waters of oxbow lakes, it was has been very successful in Barren River Lake after being introduced in the 1990s (personal communication, Eric Cummins, Southwestern District Fisheries Biologist, KY Department of Fish and Wildlife Resources, 970 Bennett Lane, Bowling Green, KY 42104). Certain life history characteristics of the yellow bass such as reproductive cycles, food consumption, and population structure may impact the aquatic ecosystem and native populations in Barren River Lake. Collection of this information may lead to a better understanding of these impacts (Rosecchi et al. 2001; Olden et al. 2006; Ribeiro et al. 2007).

Studies regarding life history aspects of the yellow bass are few, and virtually no study has been published in recent years regarding the life history of yellow bass in southeastern, man-made reservoirs. The yellow bass has been introduced into many lakes and reservoirs throughout the United States (e.g., Helm 1964; Atchison 1967; Wright 1968; Marsh and Minckley 1982; Van Den Avyle et al. 1983). It may be useful for managers to have access to yellow bass life history information in order to assess the effects of this introduced species on their systems.

The white bass, *Morone chrysops,* is a congener of the yellow bass and was an important game species in Barren River Lake through the 1990's. Since the late 1980's, the white bass population has been in decline and has been virtually eliminated from the Barren River Lake fish community (personal communication, Eric Cummins, Southwestern District Fisheries Biologist, KY Department of Fish and Wildlife Resources, 970 Bennett Lane, Bowling Green, KY 42104). In light of recent declines in the native white bass population, the present study may elucidate possible ecological overlaps between white bass and the newly introduced yellow bass in Barren River Lake. The present study addresses five questions about the life history traits of the yellow bass in Barren River Lake: 1) What is the age structure of the population? 2) What is the timing of gamete production and the annual spawning event? 3) What are the growth rates of the individual age classes in the population? 4) How does the condition of yellow bass change throughout the year? 5) What are the seasonal feeding habits of yellow bass in Barren River Lake?

Methods

The study was conducted on Barren River Lake (36.8931° N; 86.1250° W), encompassing portions of Barren and Allen counties in south-central Kentucky, U.S.A. Barren River Lake is a man made flood-control reservoir created in 1964 (Jacobs and Swink 1983) by the construction of the Barren River Lake Dam across the channel of the Barren River. Damming of the Barren River inundated three major arms of the reservoir, Barren River to the south, Peter Creek to the east, and Skaggs Creek to the north. All three feed into the main basin of the reservoir east of the dam. The shoreline of Barren River Lake is characterized by deeply incised banks comprised mostly of rock walls and occasional sandy beaches. The reservoir is held at summer pool level, covering 4,047 hectares, from April to October. Draining of the reservoir begins in October, reaching winter pool level by December covering 1,758 hectares. The reservoir is held at winter pool level until March (Jacobs and Swink 1983). The watershed surrounding the lake is almost entirely agricultural and forest (personal observation), however, there are a few houses scattered along the shoreline. In addition to the original purpose of flood-control, Barren River Lake is also used for municipal water supply and recreation (fishing and boating).

Fish collections were made via a boat-mounted electrofishing unit in shallow, littoral areas. Three general areas of Barren River Lake were selected where yellow bass were consistently present: an area in Skaggs Creek (north arm) near the Beaver Creek boat landing (36.9167° N; 86.0333° W), an area in the upstream inundated portion of Barren River (south arm) near Walnut Creek marina (36.8° N; 86.05° W), and an area in the main reservoir basin near Peter Creek and Barren River State Park (36.8833° N;

86.0667° W; Figure 1). All data from the three sampling areas were pooled for analysis. Monthly collections in each of the three areas were made between March 2008 and March 2009. Collections were not made in September 2008, December 2008, and January 2009 due to equipment malfunction. A single shock period of 900 seconds was performed during each sampling event. All yellow bass individuals were dip netted and placed into a live well until the end of the 900-second shock period. After the shocking event was completed, collected individuals were preserved on ice and transported back to the laboratory.

In the laboratory, all individuals were measured for total wet weight to the nearest ± 0.01 g. and total length to the nearest ± mm. The gonads were then extracted, sexed (when possible) and wet weight was measured to the nearest ± 0.01 g. The entire gut from the esophagus to the anus was extracted from the body cavity, fixed in 10% buffered formalin and preserved in ethanol for later diet analysis. Individual stomachs were isolated and wet weight was measured to the nearest ± 0.01 g. before diet processing. Most diet items were identified to the ordinal level, with some items being identified to the family or genus level when practical. Using an ocular micrometer, a head capsule width was measured to the nearest ± 0.001 mm for insect larvae, backbone length for fish, and a body total length for zooplankton. Measurements were then entered into published regression equations (Dumont et al. 1975; Sage 1982; Strange and Pelton 1987; Wahl and Stein 1991; Benke et al. 1999) to yield an estimated dry weight for each diet item.

To examine the age structure of the population, each fish was aged. Individual fish age can be obtained by extracting the sagittal otoliths from the base of the skull and counting the number of rings or annuli, each of which represent one year of growth (Murphy and Willis 1996). Each otolith was extracted using forceps from the base of the skull through the opercular cavity. Otoliths were placed into a small Petri dish filled with 99.9% glycerin and examined using a dissecting microscope and a fiber-optic light from the side to reveal annuli.

To investigate the timing of gamete production and the annual spawning event, the gonadosomatic index (GSI), a ratio of gonad mass to total body mass, was calculated for each individual with developed gonads. The calculated GSI yields a numerical representation of each individual's reproductive readiness, and this information combined with the time of collection can provide information regarding the timing of gamete production and the annual spawning event (Murphy and Willis 1996). A total of 239 adults were included in the analysis of GSI. Because the data were not normally distributed, a Kruskal-Wallis test with multiple comparisons (*alpha* corrected for the number of comparisons) was performed to investigate differences in GSI mean rank among sampling months using Statistica 7 (Statsoft, Tulsa, OK). To investigate the time of year at which large, breeding adults begin producing gametes for the next breeding season, a Kruskal-Wallis test with multiple comparisons was performed including 80 adults ages 5 and 6 using Statistica 7 (Statsoft, Tulsa, OK).

To characterize the growth rates of the individual age classes and to arrive at predicted mean length-at-age values, the von Bertalanffy growth function (VBGF; von Bertalanffy 1938; Kohler and Hubert 1999) was restricted to individuals collected in the warm months of 2008 (June–October) to model the declining growth rate of yellow bass using the equation,

$$l_t = L_\infty[1 - e^{-K(t-t_0)}],$$

where L_∞ is the maximum mean total length that a yellow bass would reach if it lived to age infinity, K is a constant known as the growth parameter, and l_t is the mean total length at age t. To arrive at the value for K, a regression of l_{t+1} on l_t was performed, and the slope of this regression was used in the equation,

$$K = -\ell n(slope).$$

To arrive at the value for L_∞, the slope and the intercept from the regression of l_{t+1} on l_t, was used in the equation,

$$L_\infty = \frac{Intercept}{1 - slope}.$$

To arrive at an estimation of t_0, a regression of $\ell n(L_\infty - l_t)$ was performed, and the slope and intercept of this regression was applied to the equation,

$$t_0 = \frac{Intercept - \ell n(L_\infty)}{K}.$$

Mean monthly relative weight was used to investigate the condition of yellow bass as it changed throughout the year. A standard weight was calculated for each yellow bass using the standard weight equation published by Bister et al. (2000), which provides a predicted mass of a yellow bass at a specific length. A ratio of standard mass to actual mass was then calculated to yield a relative weight for each individual, providing a avenue to compare the body condition of individuals within the population (Murphy et al. 1990, 1991). Because the data were not normally distributed, a Kruskal-Wallis test with multiple comparisons (*alpha* corrected for the number of comparisons) including 278 individuals was used to investigate the differences among monthly mean ranks of relative weights using Statistica 7 (Statsoft, Tulsa, OK).

To examine the seasonal feeding habits of yellow bass in Barren River Lake, diet items were pooled by season: winter (January–March), spring (April–June), summer (July–September), and fall (October–December). Individuals were classified as either adult or sub-adult using the presence (adult) or absence (sub-adult) of developed gonads to examine differences in diet according to life stage. A gravimetric estimation of the bulk of diet items was assessed using estimated dry weight (Hyslop 1980). Stomachs containing no identifiable prey items were considered empty and the proportion of empty stomachs to stomachs containing diet items was expressed as a percentage of total stomachs collected by season.

Results

A total of 336 yellow bass, consisting of 135 females, 103 males, and 98 sub-adults, were collected in 30 samples between March 2008 and March 2009. An amount of 145 individuals were collected from the north arm, 78 from the south arm, and 113 from the main reservoir. Captured individuals ranged from 18–267 mm in total length and 0.01–201.81 g in total wet weight. Mean total length was 134.9 mm and mean total wet weight was 40.4 g (Tables 1 and 2).

All 336 yellow bass were successfully aged using sagittal otoliths. Age group 3 was the most abundant (Figure 2), representing 23.5% of all individuals captured with 33% < age 3 and 43.5% > 3.

The Kruskal-Wallis test detected overall significant differences ($H_{8,\ 239}$ = 124.6590, $P < 0.001$) among the monthly mean rank of GSI of all adult yellow bass (Figure 3). GSI was significantly higher in March through May of 2008 and drops to a lower level in June through July. In October and November 2008, GSI increased to a level not significantly different than May but still significantly lower than March and April 2008. In February 2009, GSI was significantly lower than March through May 2008. A separate Kruskal-Wallis test on the 80 adult yellow bass ages 5 and 6 indicated overall significant differences ($H_{5,\ 80} = 30.5709$; $P < 0.001$) among the sample months (Figure 4). The mean GSI of yellow bass age 5 and 6 increased during the fall 2008 and reached their maximum values in February 2009.

The calculated values for K and L_∞ were 0.2023 and 254.7 mm respectively and the VBGF mean length at age t (l_t) was calculated for each age group using the equation,

$$l_t = 254.7[1 - e^{-0.2023(t+0.4397)}].$$

The VBGF mean length at ages 0–8 respectfully were as follows: 21.7 mm, 64.4 mm, 99.2 mm, 127.7 mm, 151.0 mm, 170.0 mm, 185.5 mm, 198.2 mm, and 208.5 mm (Figure 5).

The Kruskal-Wallis test of monthly mean rank of relative weight indicated that there were significant differences ($H_{9,\,278} = 214.6524$; $P < 0.001$) among months. Relative weight during the summer months was significantly higher than those in winter months (Figure 6).

A total of 329 stomachs were included in the diet analysis. During the winter samples, 55 of the 100 stomachs were empty (55%). Within the 42 adult stomachs containing food, chironomid larvae and pupae were the most important diet item by dry weight (99.6%). Chironomid larvae and pupae contributed 100% of total dietary dry weight of three sub-adult stomachs (Figure 7).

Of the 97 stomachs examined from the spring season, 18 were empty (18.6%). Clupeids were the most important diet item within the 78 adult stomachs, comprising 90.7% of total dietary dry weight. One sub-adult stomach containing a single chironomid larva was examined from the spring season (Figure 7).

Of the 82 stomachs examined from the summer season, 10 were empty (12.2%). Clupeids were the most important diet item within 28 adult stomachs, comprising 97.9% of total dietary dry weight. Chironomid larvae and pupae was the most important diet item in 44 sub-adult stomachs, comprising 81.1% of total dietary dry weight (Figure 7).

Of the 50 stomachs examined from the fall season, 18 were empty (36%). Adult Hymenoptera was the most important diet item within the 13 adult stomachs, comprising 81.4% of total dietary dry weight. All Hymenoptera, however, were consumed by a single individual. Copepoda was the most important diet item in 19 sub-adult stomachs during fall, constituting 74.8% of total dietary dry weight (Figure 7).

Discussion

Age 3 yellow bass were the most common during the study period, accounting for 23.5% of the total catch. Similarly, Bailey and Harrison (1945) reported variability in the strength of age classes of yellow bass in Clear Lake, Iowa. The current study suggests variability in the strength of age classes in Barren River Lake yellow bass. The oldest yellow bass captured during the study period were two individuals of age class 8; this is consistent with a study conducted by Collier (1963), who reported that a small portion of yellow bass in Clear Lake, reached 8 years of age.

The timing of gamete production can be addressed using the GSI data. Large, breeding adult yellow bass in Barren River Lake showed an increase in mean GSI during fall, indicating that gamete production had begun. These data suggest that large, breeding adults in Barren River Lake being gamete production in preparation for the following years spawning event in the fall. Bulkley (1969) reported that yellow bass showed an increase in mean GSI during late-October, suggesting that the yellow bass of Clear Lake also begin developing gonads for the following year's spawning event in fall.

The timing of the annual spawning event can also be addressed using information from the GSI analysis. GSI reached its highest point of the year in April and a low number of fish were collected in May (Table 1). The low sample size in may have been a result of yellow bass migrating up the arms of Barren River Lake to spawn as is typical of yellow bass in other lakes (Burnham 1910; Atchison 1967; Bulkley 1969). By June, fish were collected in larger numbers, many having small gonads. These data indicate that

Barren River Lake yellow bass spawn in May. Although timing of spawning was similar to that in other lakes, there was a marked difference in maximum GSI observed. Yellow bass in Clear Lake reached a maximum mean GSI of 0.08-0.16 (Bulkley 1969), this being about twice the maximum mean GSI (0.0516) of yellow bass in Barren River Lake.

The growth rates of the individual age classes of yellow bass in Barren River Lake are characterized by the predicted VBGF mean length-at-age values. The mean lengths predicted for yellow bass in Barren River Lake are shorter than mean lengths reported by Collier (1963). In his study, Collier found the mean total length of age class 6 to be approximately 292.1 mm, while the mean total length of age 6 yellow bass in Barren River Lake was 185.5 mm. This marked difference of 106.6 mm in mean total length between Collier's study and the current study indicates yellow bass in Barren River Lake may be growing slower and attaining shorter mean total lengths than other populations.

According to the VBGF, the maximum mean length attainable by yellow bass in Barren River Lake is 208.5 mm. Collier (1963) reported the individual with the longest total length in his study was in age class 6 at 309.9 mm, while the longest individual collected during the current study was in age class 8 at 267 mm. The difference of 42.9 mm between the two individuals and considering that the longest individual in Collier's study was 2 years younger compared to the longest individual in the current study may be further evidence suggesting the population of yellow bass in Barren River Lake grow slower and attain shorter mean lengths than other populations.

Condition of the yellow bass in Barren River Lake was highest in summer and declined throughout the rest of the year. Condition was lowest during spring as fish were preparing to spawn. These changes in condition, as measured by mean relative weight, are most likely attributed to the seasonal availability of diet items. The frequency of empty stomachs was lowest in summer and highest in winter. The low relative weights observed in fish during spring 2008 are especially notable because this was the same period when fish had their highest GSI. This indicates yellow bass may have been converting stored energy, rather than energy derived from the diet, into gametes during the winter.

Sub-adult yellow bass relied mostly on chironomid larvae and pupae throughout spring, summer, and winter. In summer and especially in the fall, sub-adults began feeding on Copepods, suggesting that Copepods had become an abundant food source by fall. This suggestion is consistent with previous studies showing that Copepod populations and production can have a peak in late-summer and fall (Pennak 1949). The absence of fish in the diet of sub-adult yellow bass indicates that sub-adults had not yet reached a size large enough to consume fish.

Adult yellow bass fed mostly on young-of-year gizzard shad during the spring and summer. This indicates that yellow bass began feeding on young-of-year gizzard when they became available in the spring. By fall, however, gizzard shad had disappeared from the diet completely, indicating that young-of-year gizzard shad had grown outside of the gape limit of yellow bass. Adult yellow bass diet then shifted back to aquatic insect larvae during fall and winter. A similar pattern was observed in other Kentucky reservoirs where shad were only susceptible to predation by white crappie (*Pomoxis annularis*) for approximately 1-3 months in the summer due to gape-limitation (Hale 1996). Considering the higher proportion of empty stomachs, their inability to consume gizzard shad, and the lower overall food consumption, adult yellow bass may be starving during winter.

A study conducted by Kraus (1963) in Clear Lake, Iowa, indicated that young yellow bass consumed mostly entomostracans (i.e. planktonic copepods and cladocerans), chironomid larvae, and *Hyallella* spp. In a study conducted by Driscoll and Miranda (1999), young yellow bass of Eagle Lake, Mississippi, were reported to consume mostly fish eggs (41%), chironomid larvae (29%) and amphipods (14%). Considering that *Hyallella* sp. is contained within the order Amphipoda and that amphipods, copepods and cladocerans are all crustaceans, these two studies indicate that young yellow bass consume mostly small crustaceans. The major difference between the two studies is that Driscoll and Miranda (1999) found fish eggs to be the most important diet item by wet weight for young yellow bass. Fish eggs were not present in the diet of young (sub-adult) yellow bass in Barren River Lake.

According to Kraus (1963), immature insects, such as dipteran larvae, and planktonic crustaceans, such as amphipods, cladocerans, and copepods, were highly important to the diet of adult yellow bass in Clear Lake, Iowa. Collier (1963) reported that adult yellow bass fed mostly on forage fish, including young yellow bass and young gizzard shad (*Dorosoma cepedianum*), in North Twin Lake, Iowa. Driscoll and Miranda (1999) reported the most important diet item by percent wet weight was fish (27%), including threadfin shad (*D. petenense*), inland silverside (*Menidia beryllina*) and western mosquitofish. Fish eggs, however, were second in importance by percent wet weight (20%). Besides the absence of fish eggs, the diet of adult yellow bass in Barren River Lake was found to be similar to these three studies.

Yellow bass of Barren River Lake are smaller in size, have slower growth and are in lower condition when compared to the previous studies. As mean GSI increases during late fall and winter, mean relative weight and food consumption drops to its lowest point of the year. The increased GSI observed during winter indicates that these fish are converting energy stored in the body to produce gametes in preparation to spawn. The production of gametes at a time when food resources are scarce results in very low body condition as revealed by the decreasing relative weight during this period. These phenomena suggest that the yellow bass of Barren Rive Lake are starving over winter.

There are various ways that a native predatory fish species can disappear from a stream, lake, or reservoir (e.g, environmental changes, predation, and competitive displacement). Changes to the native environment, such as acidic precipitation leading to the acidification of lakes, have been associated with the disappearance of trout species in North America and Europe (Hendrey et al. 1976). Predation by introduced sea lamprey led to the near extinction of the upper Great Lakes lake trout in the 1940s (Eschmeyer 1957; Lawrie 1970; Hansen 1999). Another phenomenon leading to the disappearance of native predatory fish species is competitive displacement by an introduced fish species (Townsend and Crowl 1991). Life history traits of the native and introduced species can overlap, leading to competition for resources such as food and space (Mittelbach 1988; Townsend and Crowl 1991; McDowall 2003; Beisner et al. 2003). Comparison of the life history traits of yellow bass and white bass in Barren River Lake would elucidate possible competitive interactions between these two species.

Although there is no published data on life history traits of white bass in Barren River Lake, there have been many studies on the species in reservoirs. Being cogeners, there are many similarities between the white bass and the yellow bass. The white bass, like the yellow bass, travels upstream to spawn in running waters during the spring (Bonn 1953; Priegal 1971). A study conducted by Van Den Avyle et al. (1983) found no distinct segregation of habitat use between young white bass and young yellow bass. A review of previous studies indicated similarities in the diet of white bass and yellow bass of the current study. Young white bass consume mostly zooplankton, such as Copepods, and Chironomid larvae and pupae (Priegle 1970; Van Den Avyle 1983). Adult white bass feed mostly on gizzard shad and threadfin shad during the summer and shift to Copepods, Chironomid larvae and pupae, and other aquatic insect larvae such as Hymenopterans, Ephemeropterans during the fall, winter, and spring (Bonn 1953; Priegal 1970; Van Den Avyle 1983). White bass in Lake Texoma, Oklahoma-Texas, displayed an annual dietary pattern similar to yellow bass in Barren River Lake. Gizzard shad were the primary diet item during the summer. When gizzard shad had grown outside of the white bass gape limit in early fall, there was a shift towards zooplankton and insect larvae (Bonn 1953). These similarities indicate the potential for competition between the yellow and the white bass of Barren River Lake.

As with most fish introductions, yellow bass may have adverse effects on the native populations of fish and the ecosystem of Barren River Lake. For instance, the population of native white bass has been in decline for the last couple decades and is now believed to be dependent on artificial stocking (personal communication, Eric Cummins, Southwestern District Fisheries Biologist, KY Department of Fish and Wildlife Resources, 970 Bennett Lane, Bowling Green, KY 42104). Although relative abundance was not measured for yellow bass or other species in this study, it is interesting to note that only a single white bass was collected during the year of sampling. The decline of the native white bass population in the Barren River Lake may be partially attributed to the introduction of the yellow bass. Although rare, white bass still occur in the lake and any life history information collected on this population would allow direct comparison with my data. Comparison of the life history traits of these two species would allow an assessment of whether yellow bass are playing a role in the failure of the white bass population. The yellow bass population in Barren River Lake is well-established and shows no signs of declining. Hence, managers must consider the effects that this burgeoning introduced population may have on the fish community of Barren River Lake.

Tables and Figures

Table 1 – Mean total length of 336 yellow bass collected in Barren River Lake from March 2008 to March 2009. No collections were made in September and December 2008 and January 2009.

Month	N	Mean (mm)	S.D.	Age	N	Mean (mm)	S.D.
Mar	33	202.2	23.0	0	13	26.0	12.6
Apr	12	183.8	30.4	1	47	60.7	13.9
May	2	172.0	14.1	2	51	107.5	28.9
June	84	155.5	39.8	3	79	142.6	47.5
July	38	128.6	61.8	4	52	166.0	28.5
Aug	49	86.1	41.4	5	58	170.0	13.4
Oct	38	120.7	63.3	6	22	184.0	13.4
Nov	12	162.4	47.0	7	12	199.7	9.1
Feb	47	112.3	27.4	8	2	236.5	43.1
Mar	21	101.8	5.7				

Table 2 – Mean total wet mass of 336 yellow bass collected in Barren River Lake from March 2008 to March 2009. No collections were made in September and December 2008 and January 2009.

Month	N	Mean (g)	S.D.	Age	N	Mean (g)	S.D.
Mar	33	65.6	27.3	0	13	0.3	0.5
Apr	12	50.9	31.4	1	47	2.1	2.2
May	2	50.7	7.5	2	51	14.1	14.0
June	84	62.1	28.1	3	79	30.5	29.9
July	38	48.4	42.6	4	52	58.2	22.9
Aug	49	13.6	21.0	5	58	68.6	19.4
Oct	38	36.1	39.7	6	22	80.6	20.7
Nov	12	57.2	53.4	7	12	101.5	19.9
Feb	47	14.9	19.9	8	2	164.0	53.4
Mar	21	9.7	1.7				

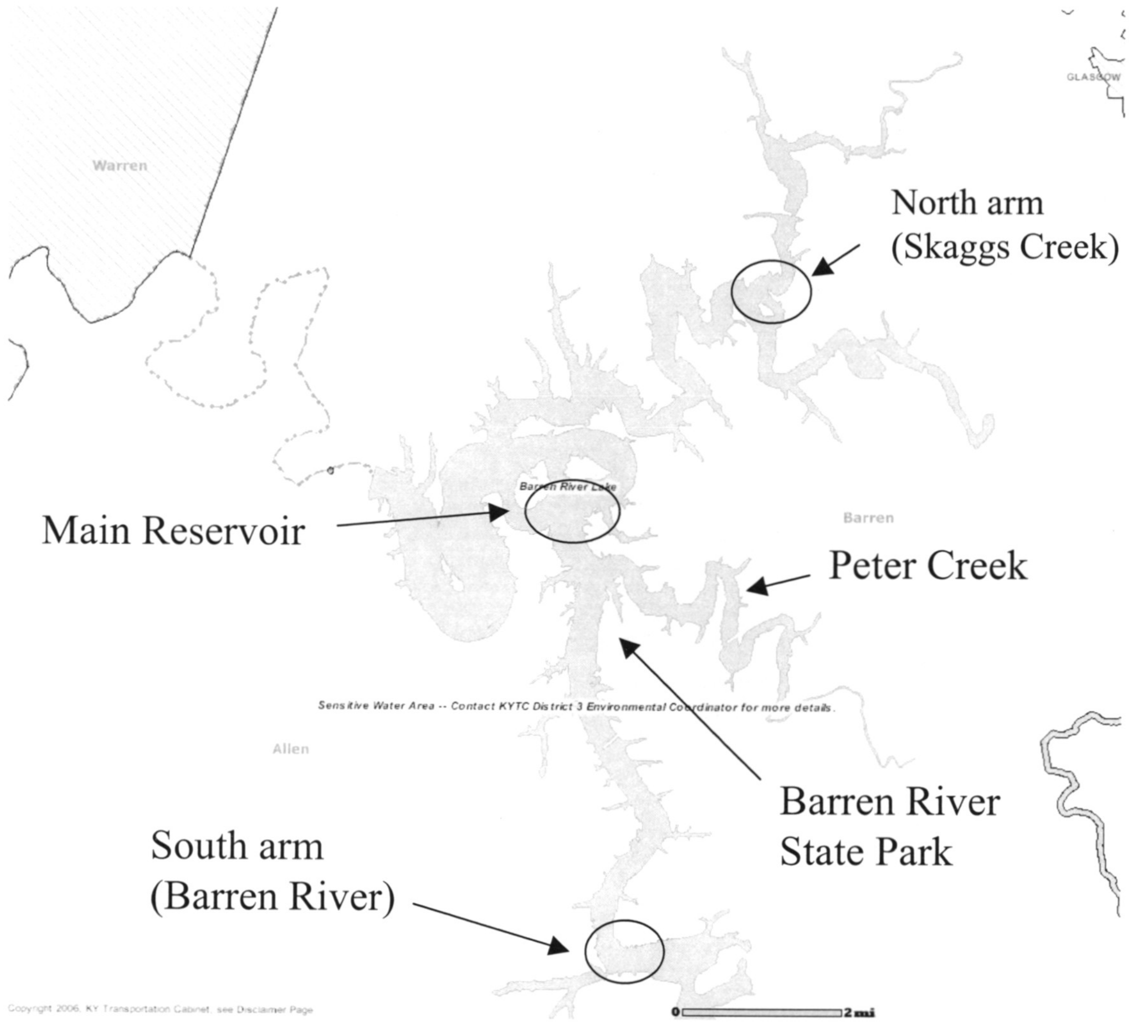

Figure 1 – Map of Barren River Lake, Kentucky. Ovals indicate approximate location of sampling areas.

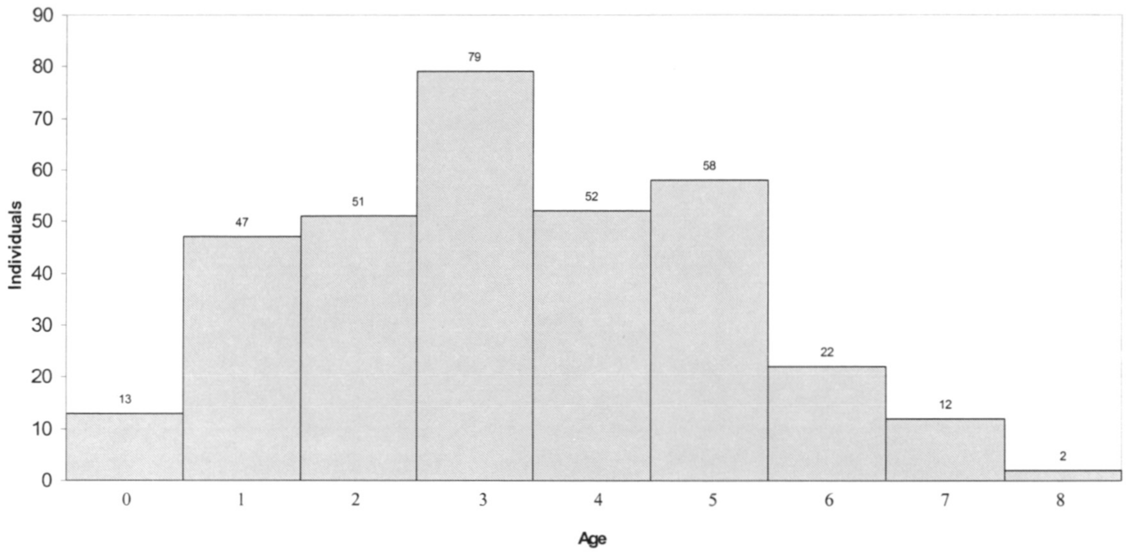

Figure 2 – Age frequency distribution of 336 Barren River Lake yellow bass collected in March 2008 through March 2009.

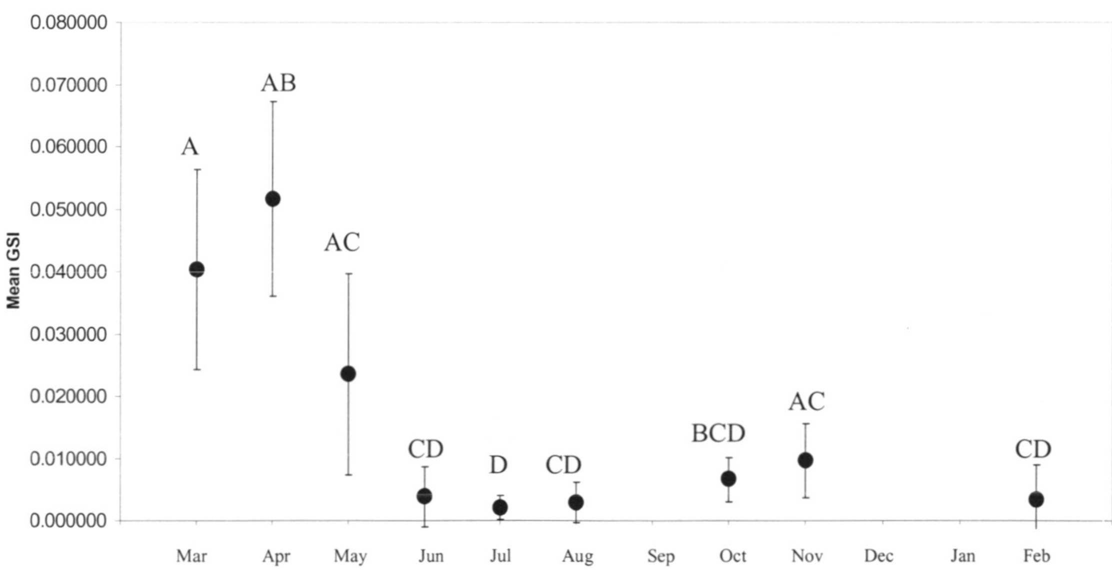

Figure 3 – Monthly GSI of all adult yellow bass. Vertical bars denote ± 1 S.D. Results of a Kruskal-Wallis test with multiple comparisons are indicated by the letters “A”, “B”, “C”, and “D”. Points bearing the same letter designation are not significantly different.

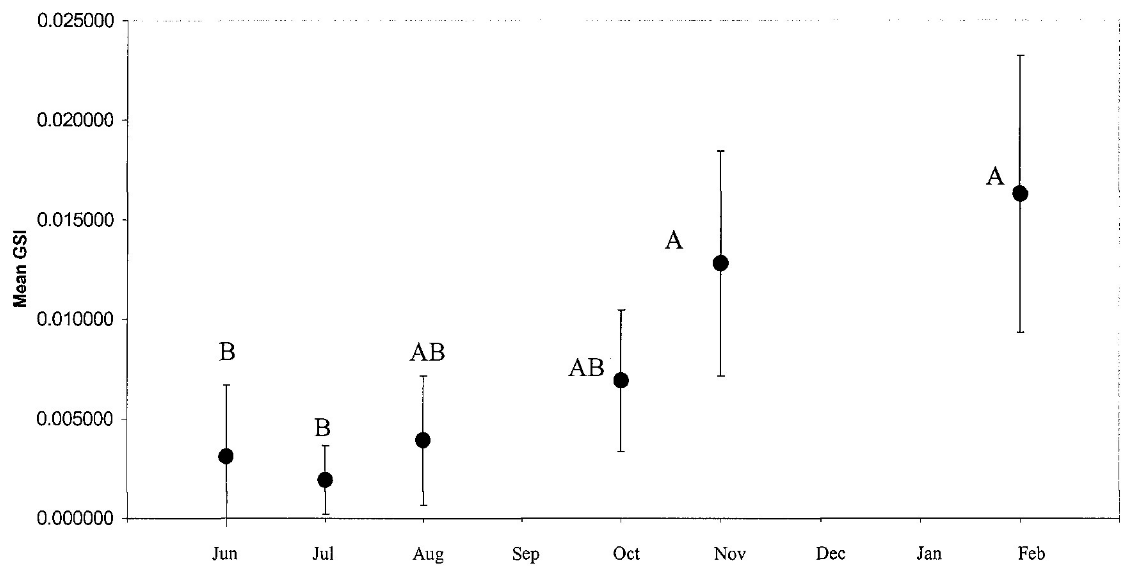

Figure 4 – Monthly GSI of adult yellow bass ages 5 and 6. Vertical bars denote ± 1 S.D. Results of a Kruskal-Wallis test with multiple comparisons are indicated by the letters "A" and "B". Points bearing the same letter designation are not significantly different.

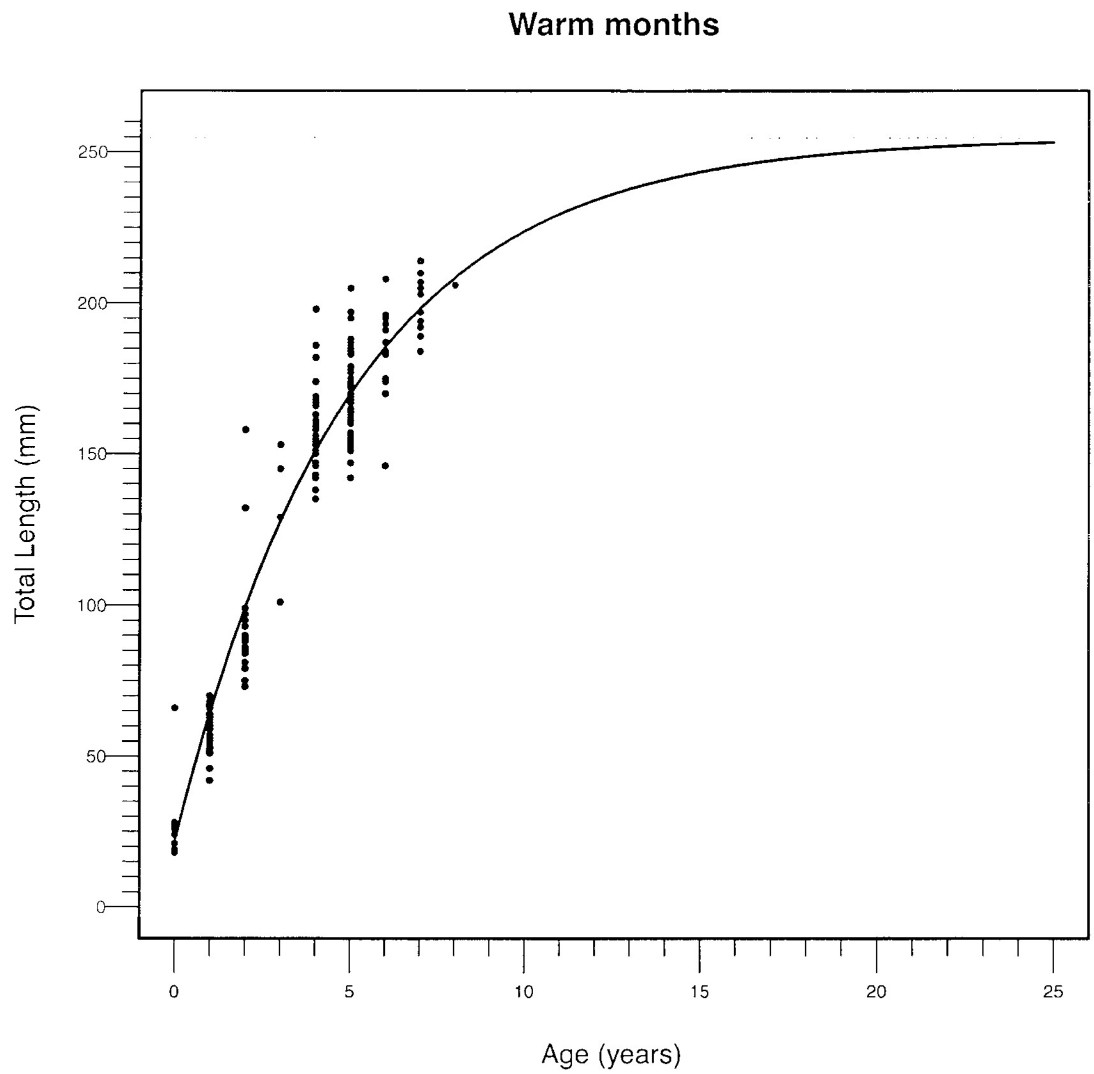

Figure 5 – The von Bertalanffy growth function (VBGF) and individual total lengths of 209 yellow bass collected in Barren River Lake during the warm months of 2008 (June–October) by age. The VBGF maximum length was 254.7 mm and the predicted mean total lengths of ages 0-8 were as follows: 21.7 mm, 64.4 mm, 99.2 mm, 127.7 mm, 151.0 mm, 170.0 mm, 185.5 mm, 198.2 mm, and 208.5 mm.

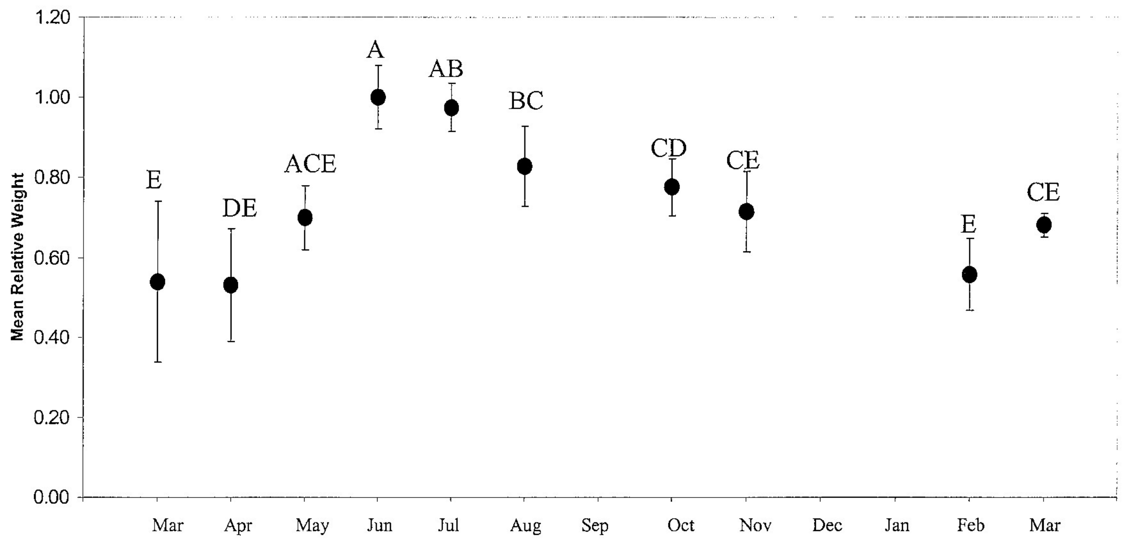

Figure 6 – Monthly relative weight. Vertical bars denote ± 1 S.D. Results of a Kruskal-Wallis test with multiple comparisons are indicated by the letters "A", "B", "C", "D", and "E". Points bearing the same letter designation are not significantly different.

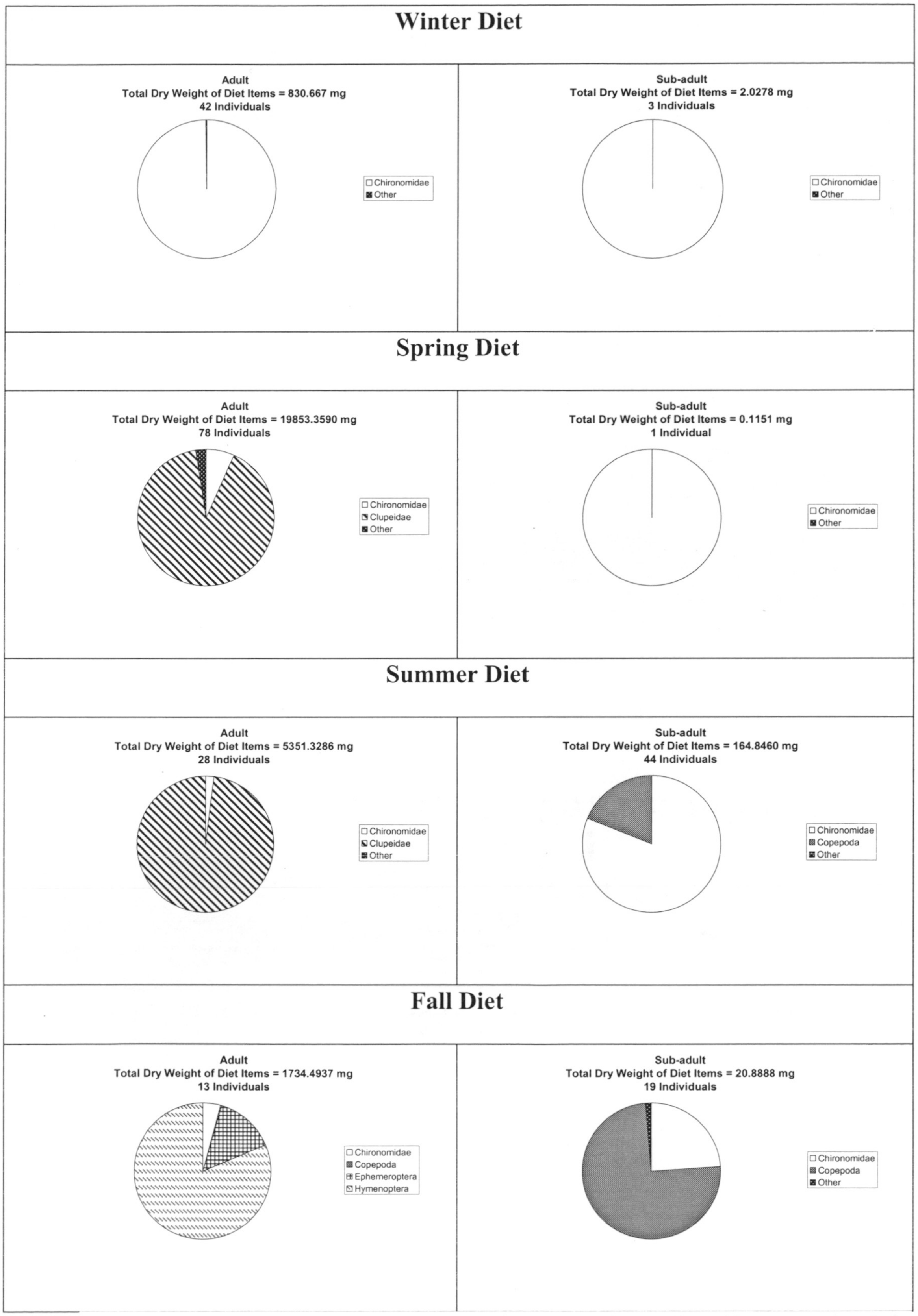

Figure 7 – Total diet item dry weight by season of 329 yellow bass collected in Barren River Lake in March 2008 through March 2009.

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